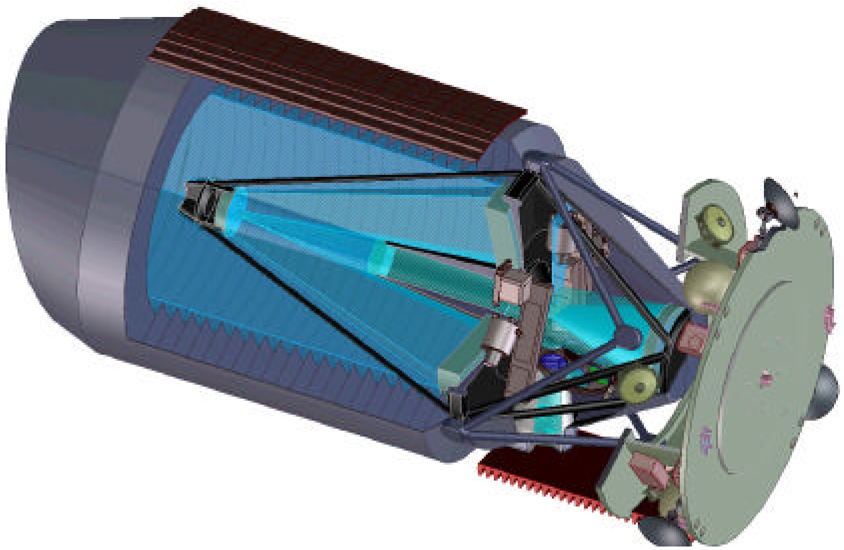
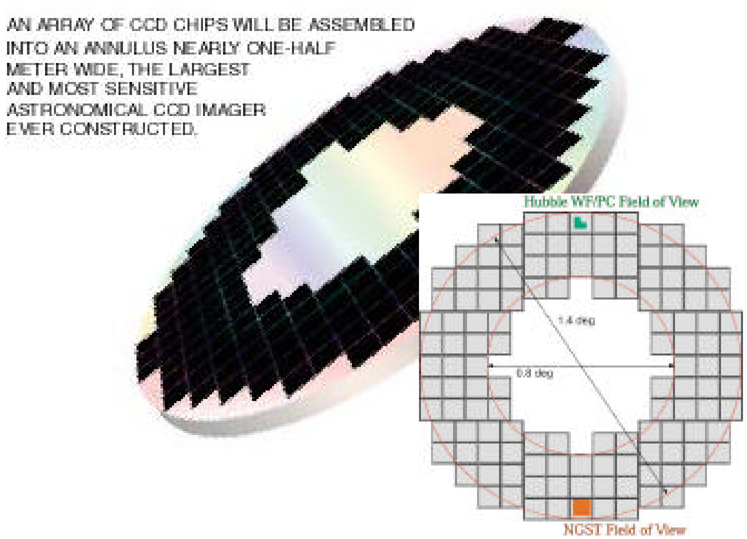
Project Overview

- SuperNova /Acceleration Probe



- R&D Plan



Talk Outline:

- Introduction
- Mission Overview & Requirements
- Payload Concepts
- Mirror Technology
- Launch Vehicle
- Instrumentation Suite
- Observing Plan
- Orbit
- Prelim. Project Organization
- Prelim. Project Schedule & Costs
- R&D Activities
- Summary

Presented by: Michael Levi
January 25, 2001

Project History and Status

- Project conceived of in March 1999.
- Sizable collaboration already exists.
- Project is being developed as a multi-agency partnership:
  - — Team that produced current results was supported by DOE, NSF, and NASA.
  - — Science review by SAGENAP of 260 page proposal March 2000: <u>strong endorsement of science and recommendation for study funding</u>.
  - — SNAP R&D proposal to NSF.
  - — NSF is already supporting CCD technology development.
  - — DOE support commenced after SAGENAP
  - — Continuing DOE support contingent upon R&D review
- Initiate study conceptual design phase (equivalent to NASA phase A) to develop CDR, cost & schedule range, key technologies.
- Cost to be determined by study phase Policy of "launch for other agencies" a route for NASA participation. A joint NSF/DOE experiment — NASA provides launch vehicle and launch services.

From Science Goals to Project Design

Science

- Measure Ω_M and Λ
- Measure w and $w(z)$

Statistical Requirements

- Sufficient (~2000) numbers of SNe Ia
- …distributed in redshift
- …out to $z < 1.7$

Systematics Requirements

Identified and proposed systematics:

- Measurements to eliminate / bound each one to +/–0.02 mag

Data Set Requirements

- Discoveries 3.8 mag before max
- Spectroscopy with S/N=10 at 15 Å bins
- Near-IR spectroscopy to 1.7 μm

⋮

Satellite / Instrumentation Requirements

- ~2-meter mirror
- 1-square degree imager
- 3-arm spectrograph (0.35 μm to 1.7 μm)

Derived requirements:

- High Earth orbit
- ~50 Mb/sec bandwidth

⋮

Mission Requirements

- Observe over 2000 type 1a Supernova
  - — Quantity: Field-of-View 1 square degree
  - — Quality: 1% cross-wavelength calibration, from 350 - 1700 nm
  - — Distribution: Ability to accurately study supernovae as far away as z<1.7

- Need consistent uniform data set where selection criteria can be applied and systematic sources can be analyzed and factored.

- Minimum data set criteria:

  1) discovery within 2 days (rest frame) of explosion (peak + 3.8 magnitude),

  2) 10 high S/N photometry points on lightcurve,

  3) lightcurve out to plateau (2.5 magnitude from peak),

  4) high quality peak spectrophotometry

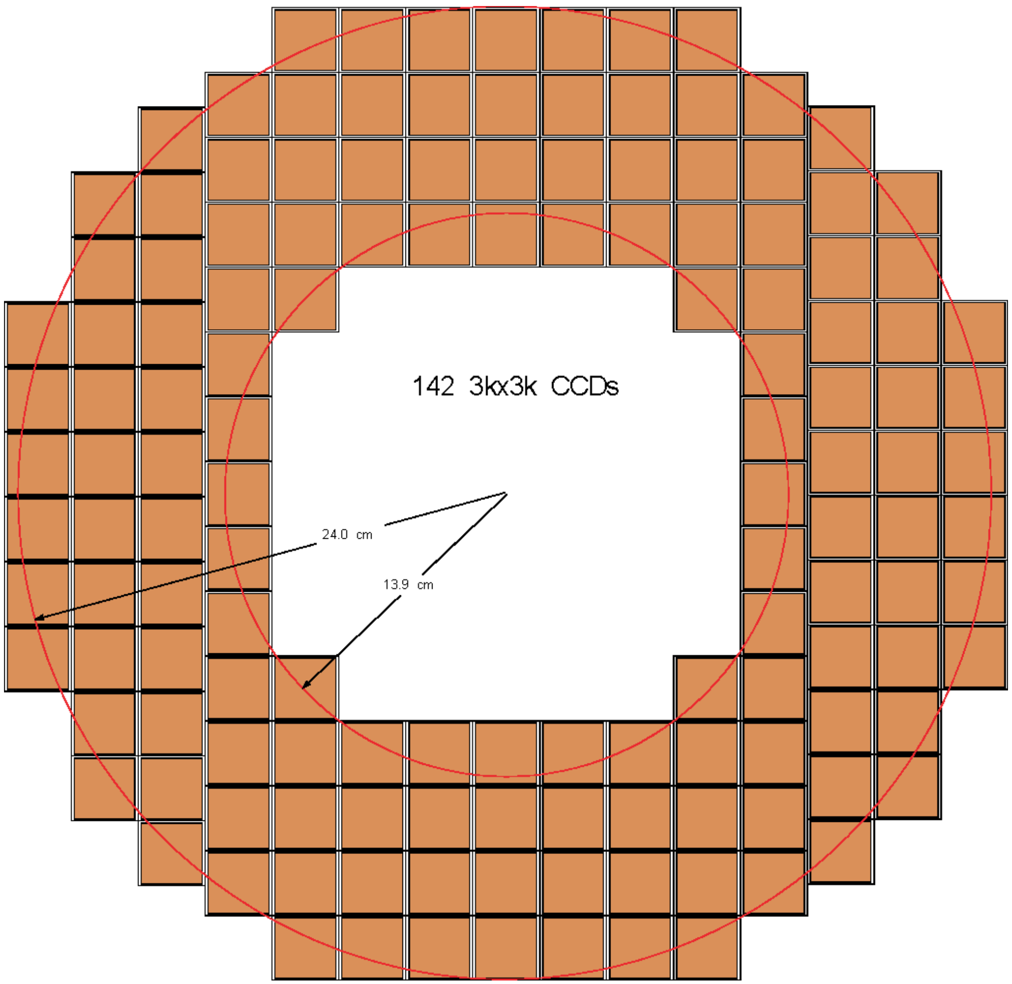
Instrumentation Requirements

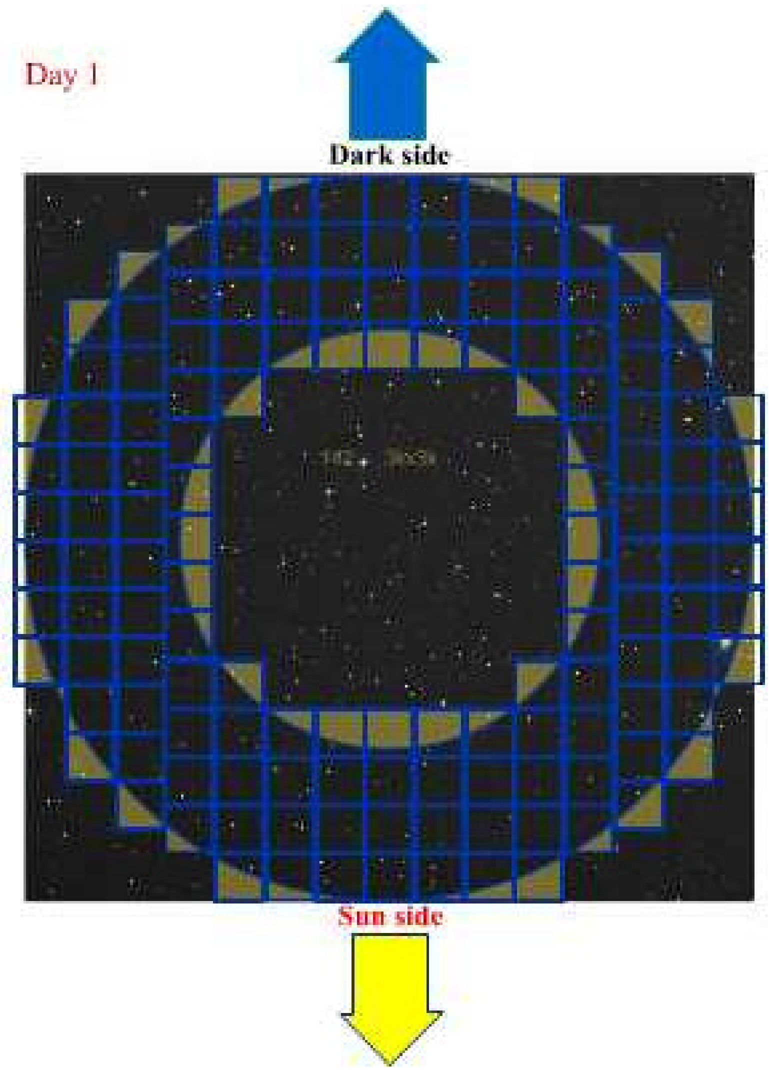
- **How to obtain both data quantity AND data quality?**
  - **Batch processing techniques with wide field -- large multiplex advantage,**
  - **Wide field imager sensitive to 30th magnitude**
  - **No trigger (*z*<1.2)**
  - **Mostly preprogrammed observations, fixed fields / spin filter wheel**
  - **Very simple experiment, passive, almost like an accelerator expt.**

- **SNAP design meets these scientific objectives**
  - **Mirror: 2 meter aperture sensitive to light from distant SN**
  - **<u>Optical Photometry:</u> with 1°x 1° billion pixel mosaic camera, high-resistivity, rad-tolerant p-type CCDs sensitive over 0.35-1μm**
  - **<u>IR photometry:</u> 1'x1' or 10'x10' FOV, HgCdTe array (1-1.7 μm)**
  - **<u>Integral field optical and IR spectroscopy:</u> 0.35-1.7 μm, 2"x2" FOV**

GigaCAM detector
Annular layout

- Layout is rotationally symmetric
- 142 3kx3k CCD's





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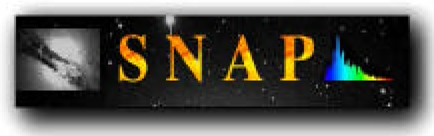

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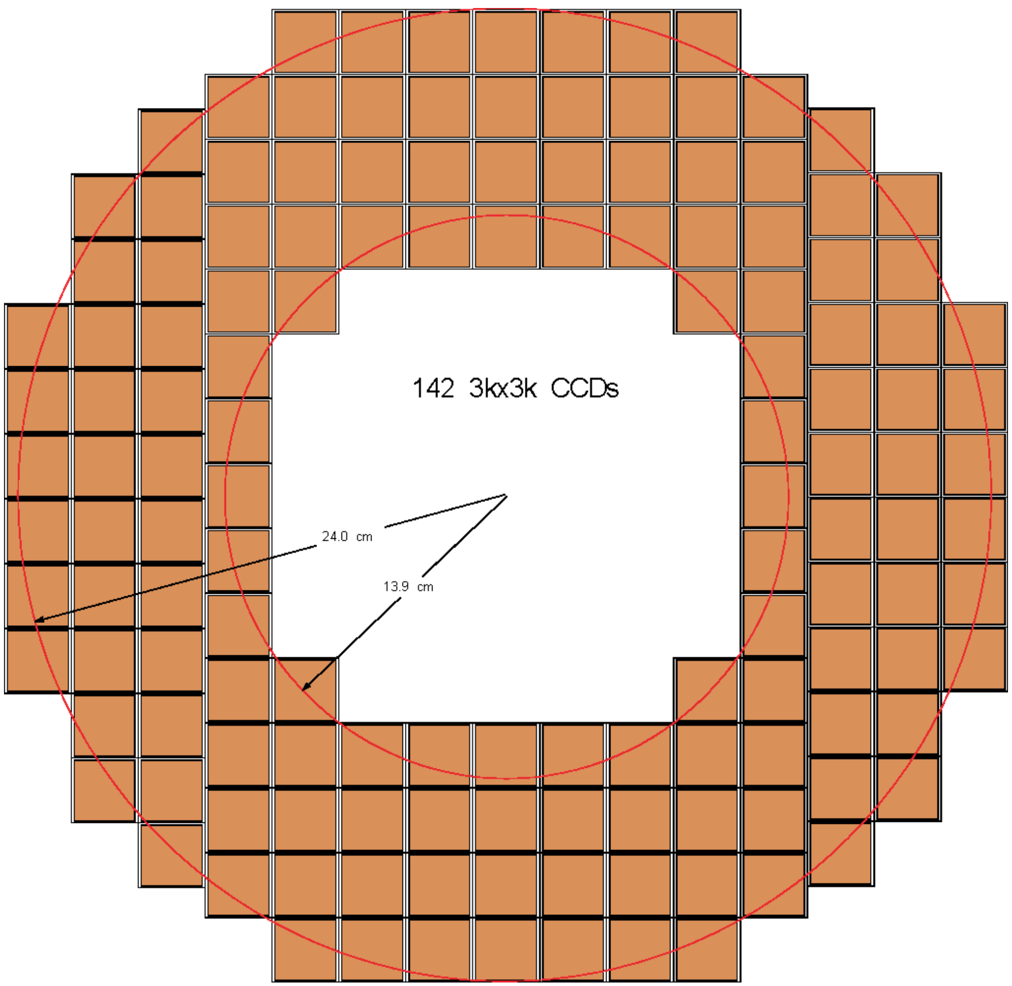

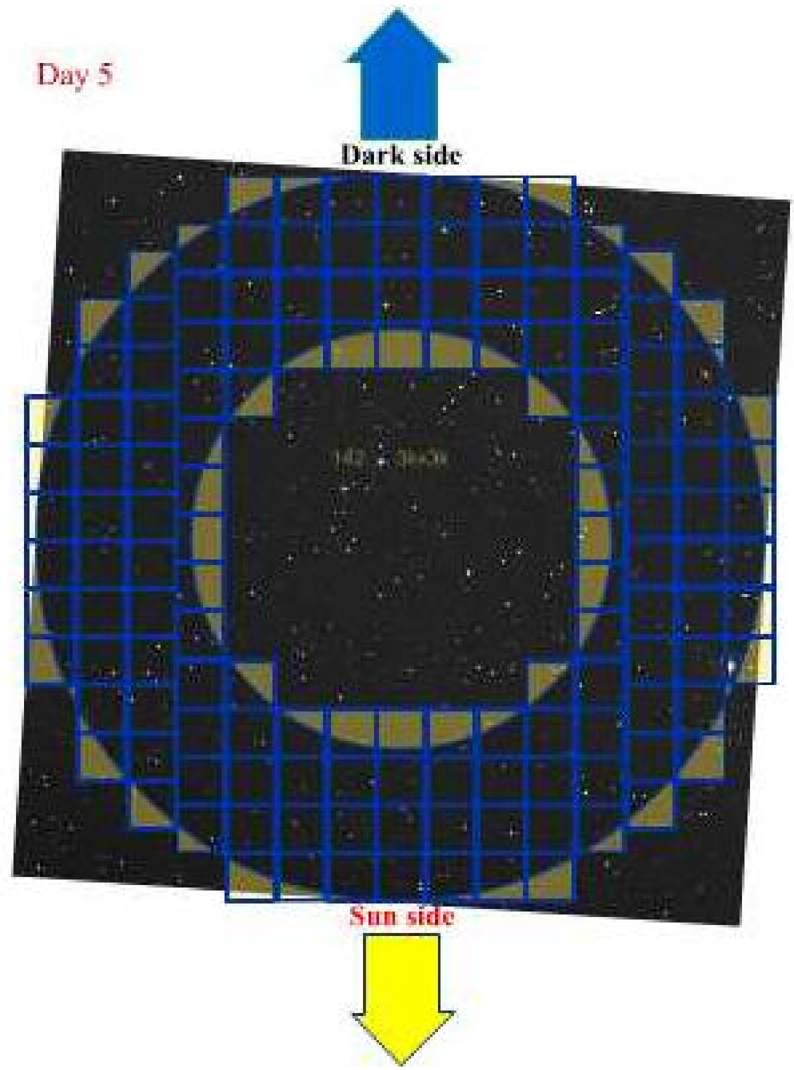

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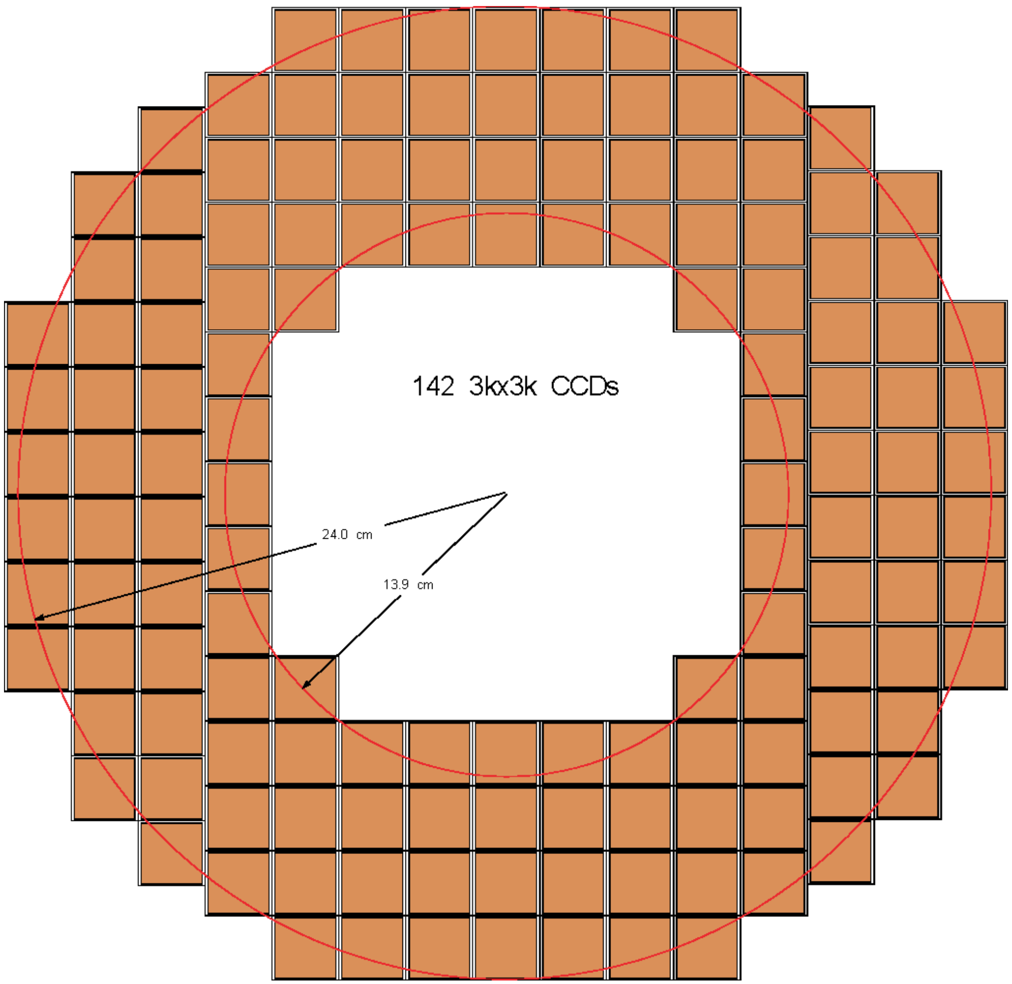

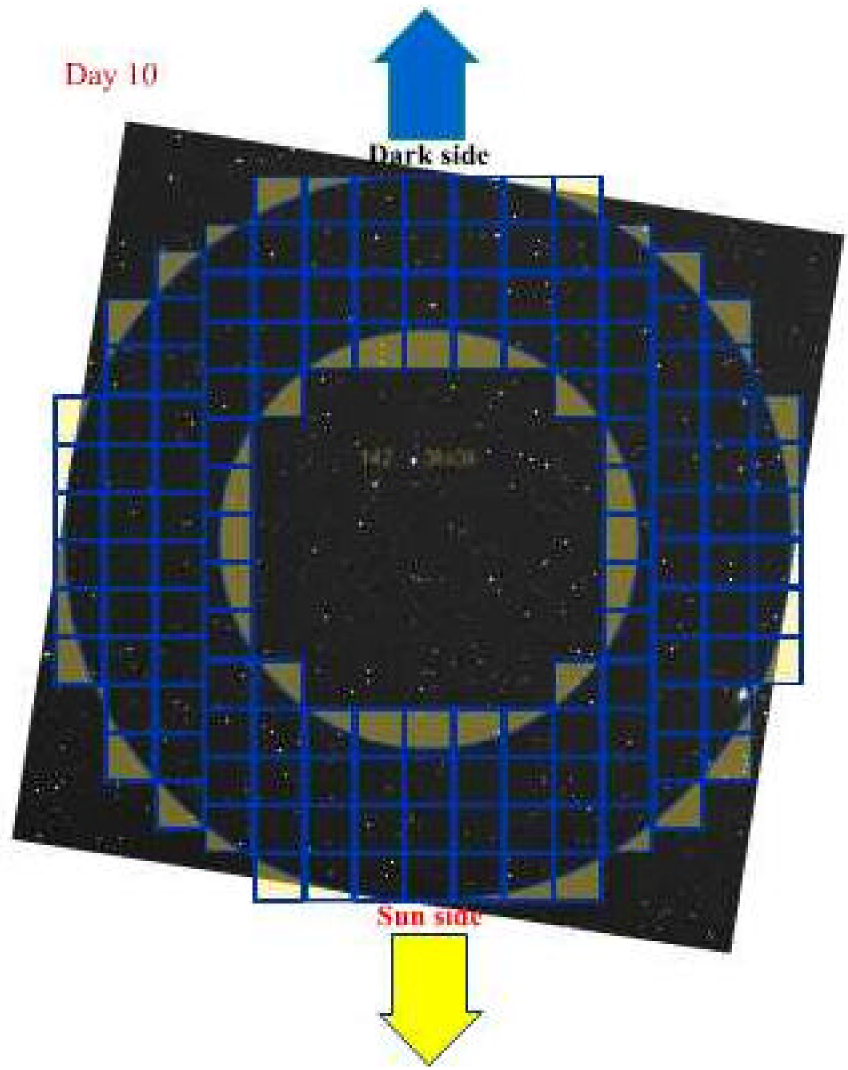

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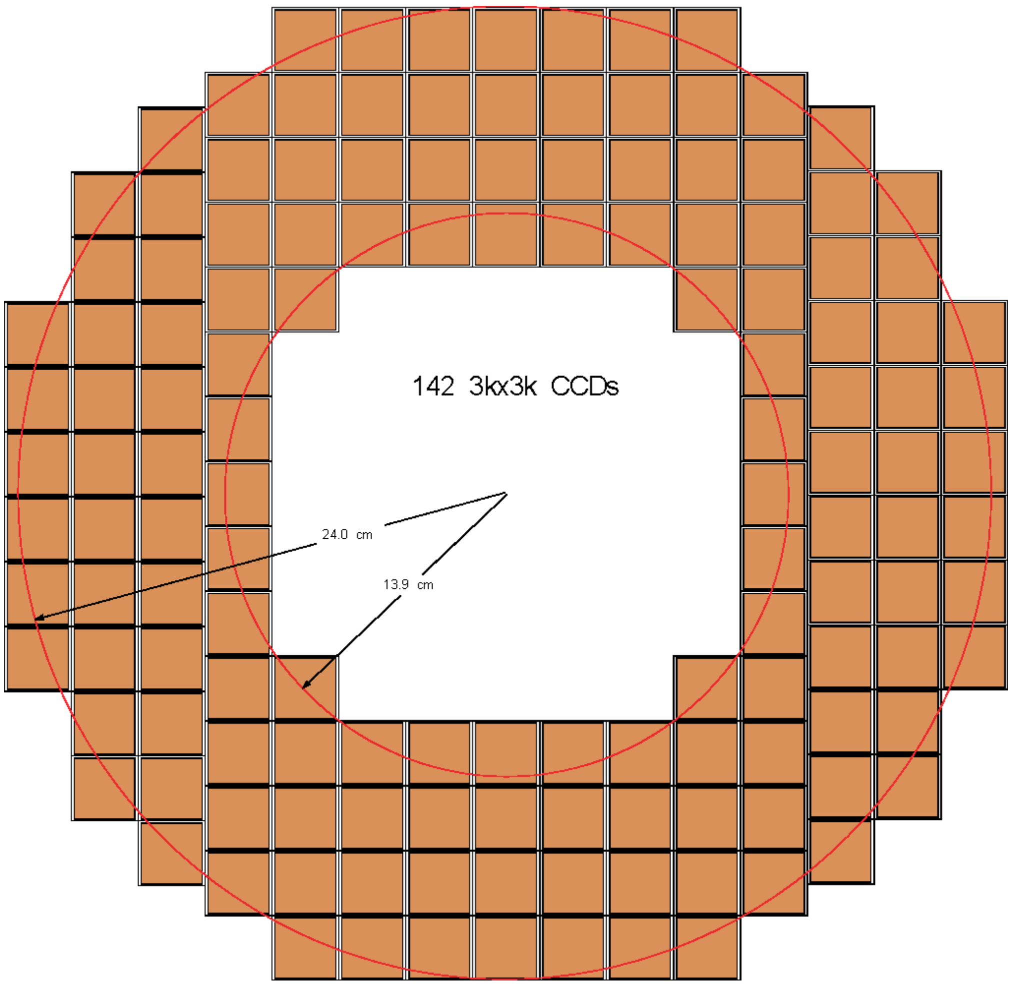

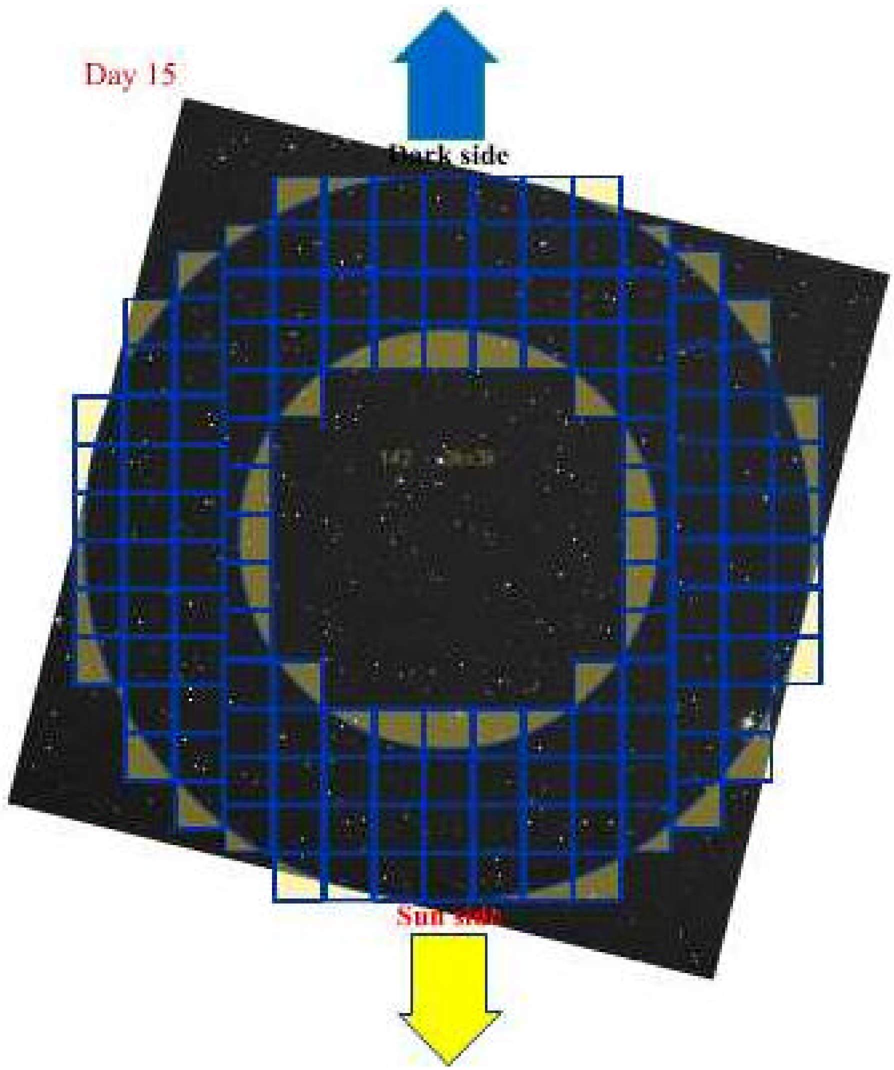

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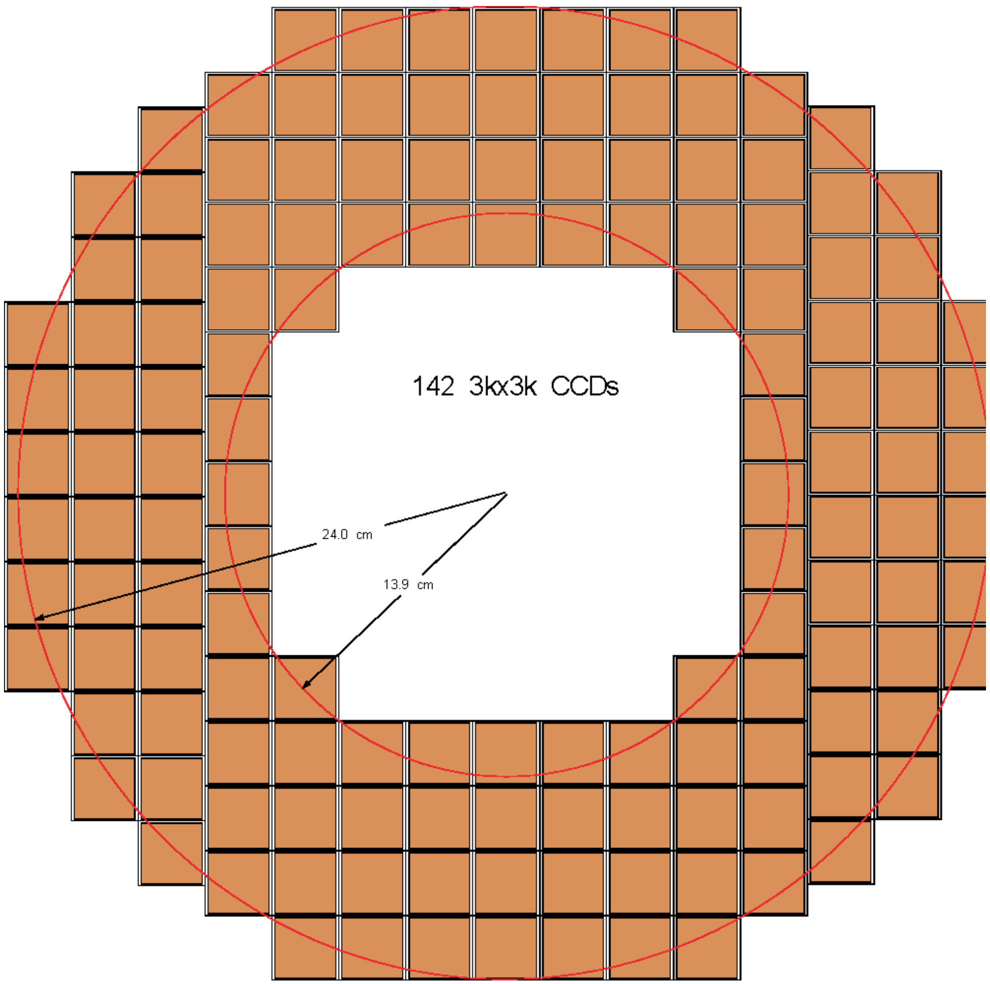
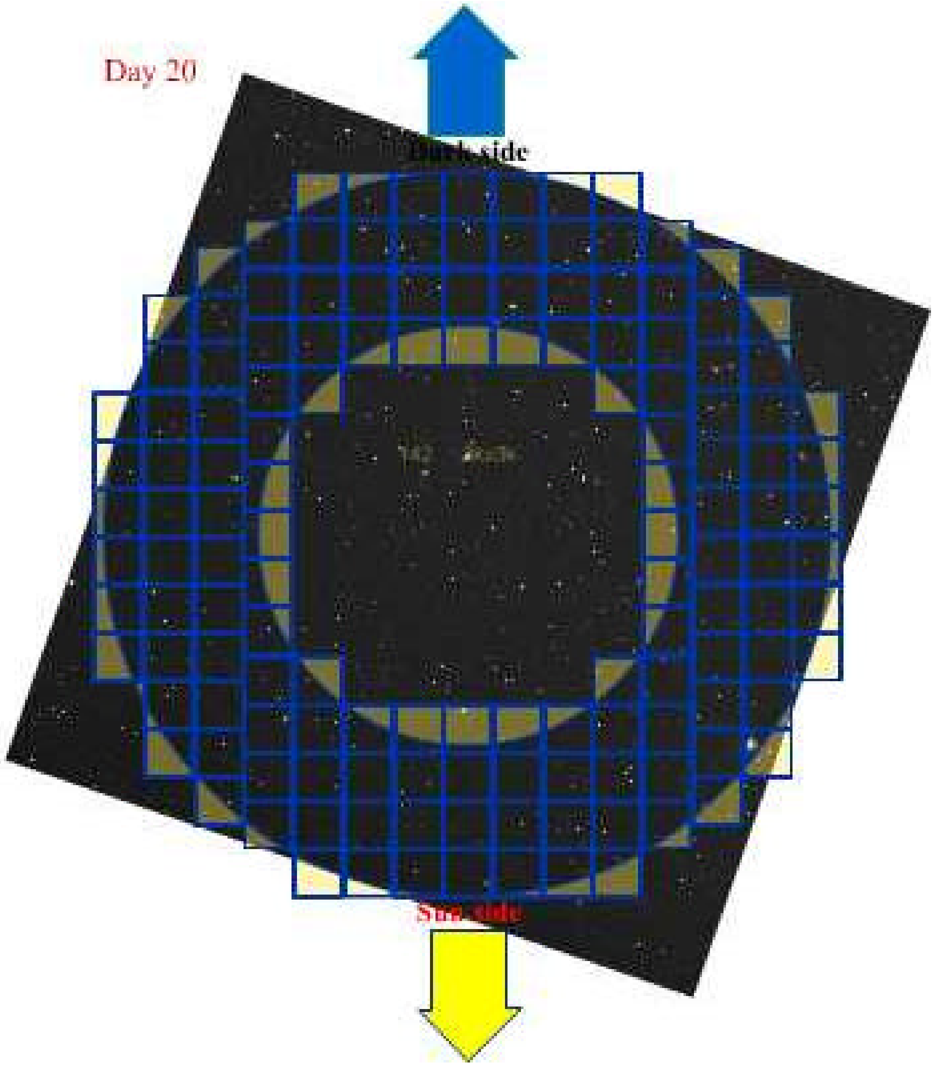


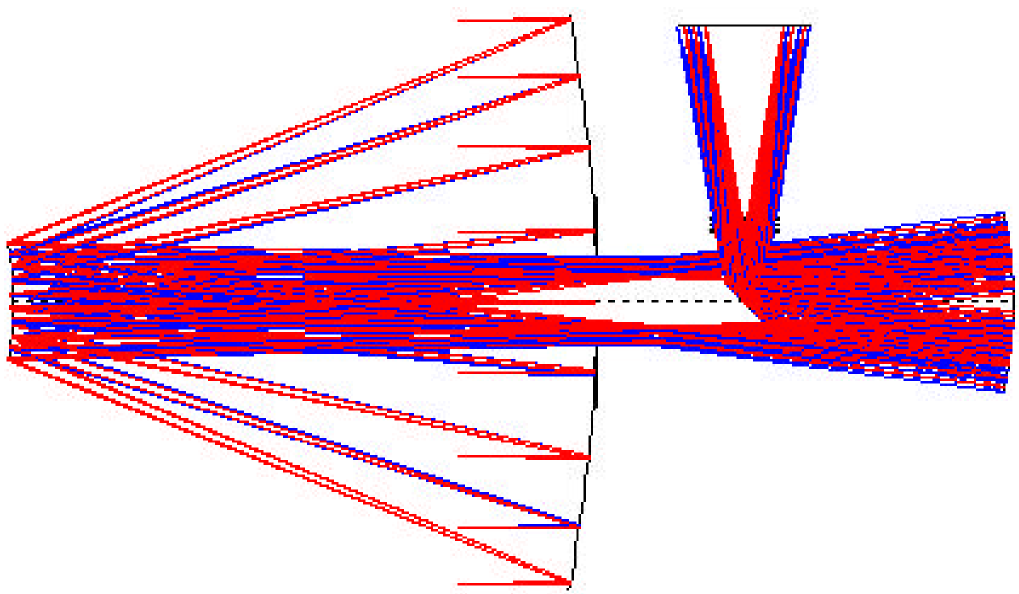


Spacecraft Assembly

Telescope Assembly

Observatory Parameters

Aperture	~ 1.8 - 2.4 meter
Field-of-view	1° x 1°
Optical resolution	diffraction-limited at I-band
Wavelength	350nm - 1700nm
Solar avoidance	70°
Temperature	Telescope 270-290K (below thermal background)
Fields of study	North and South Ecliptic Caps
Image Stabilization	Focal Plane Feedback to ACS
Plate Scale	0.07 - 0.12 arcsec/pixel

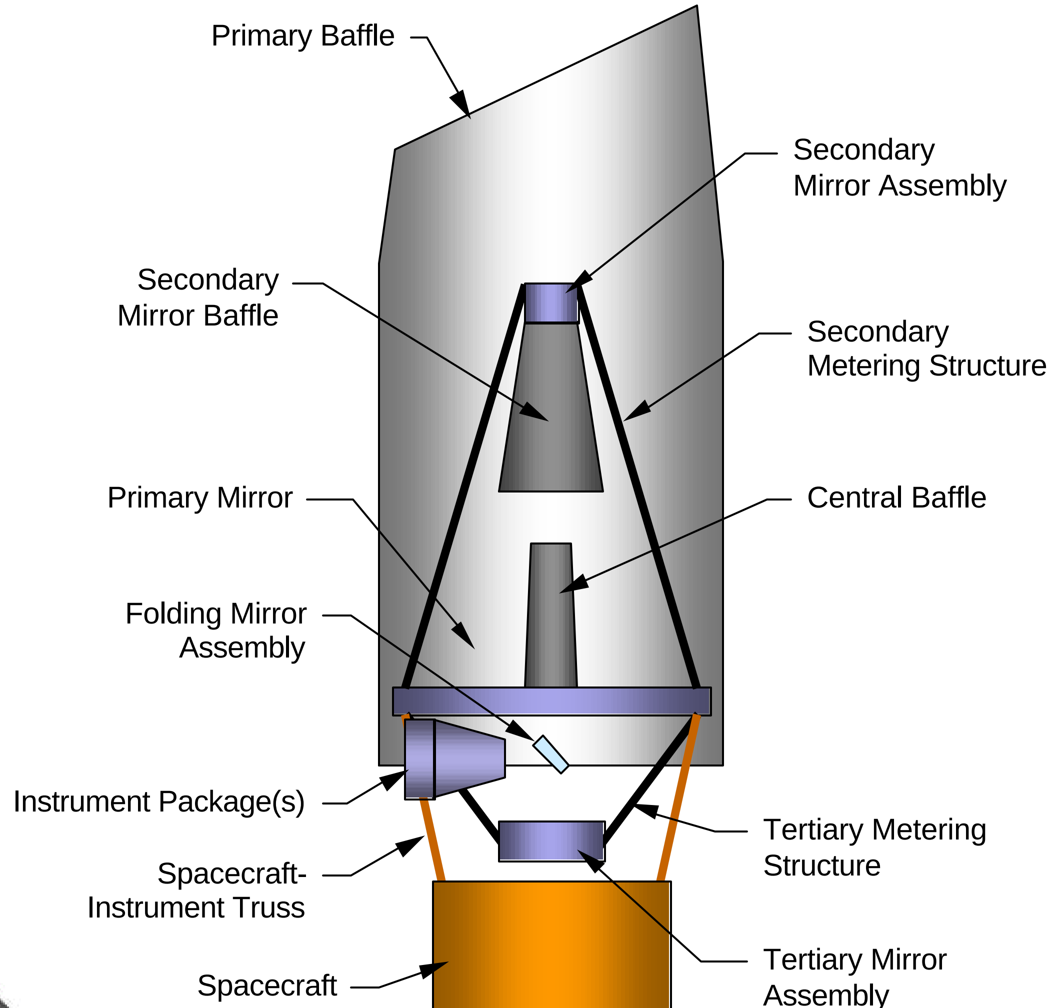


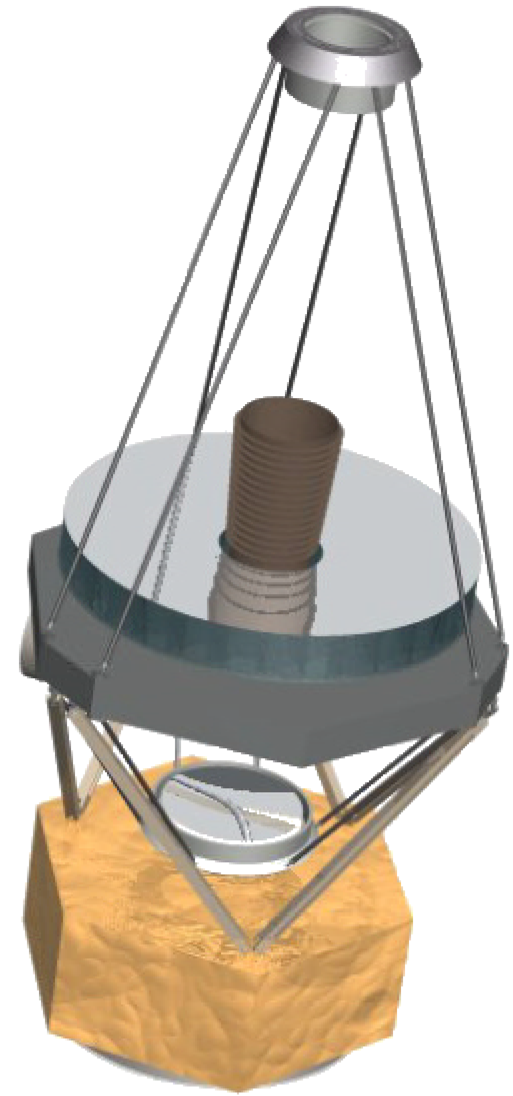
Primary Mirror
diameter= 200 cm

Secondary Mirror
diameter= 42 cm

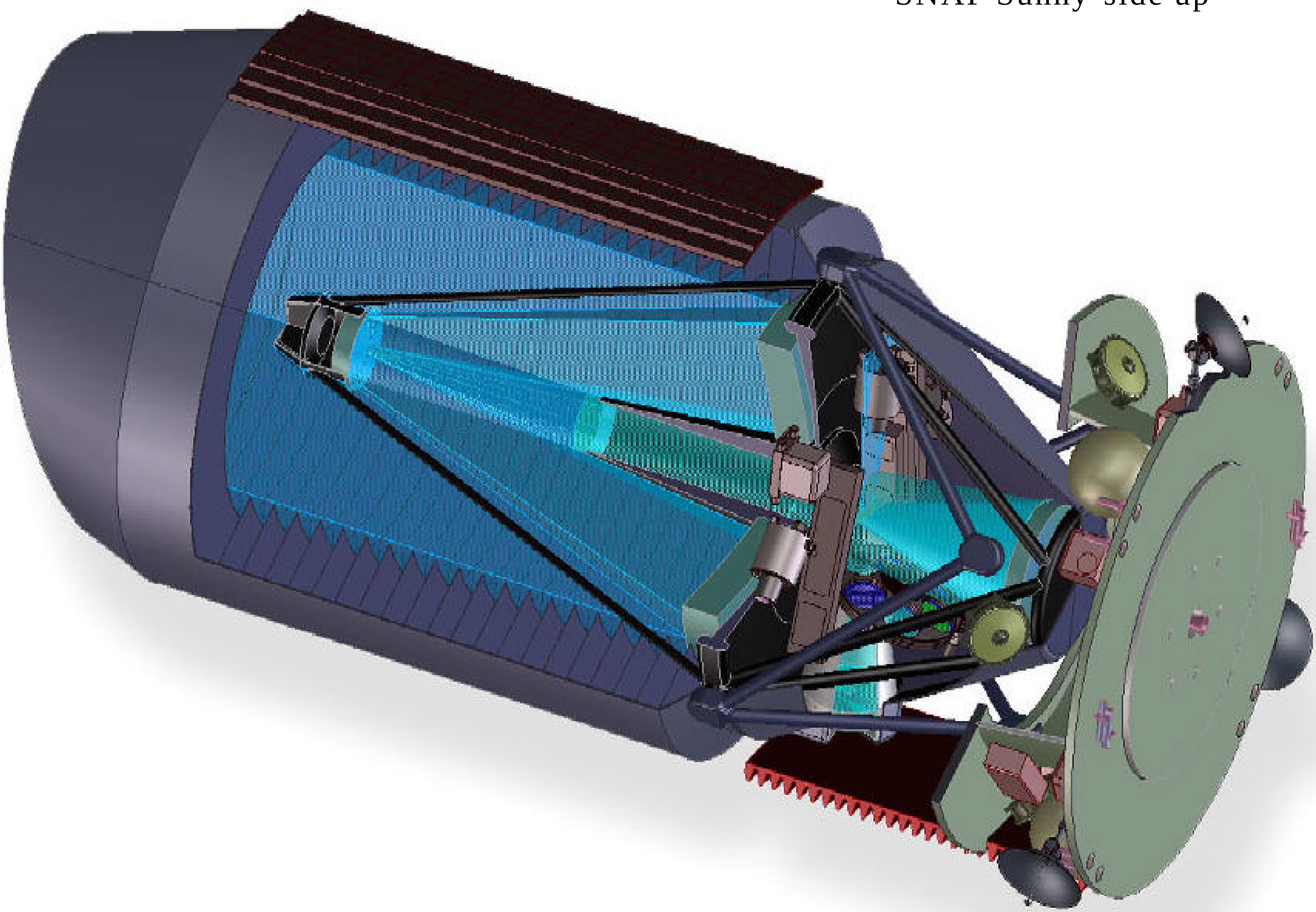
Tertiary Mirror
diameter=64 cm

SNAP Telescope - Current Structural Concept



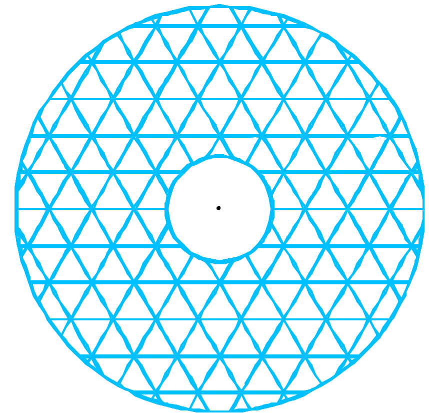


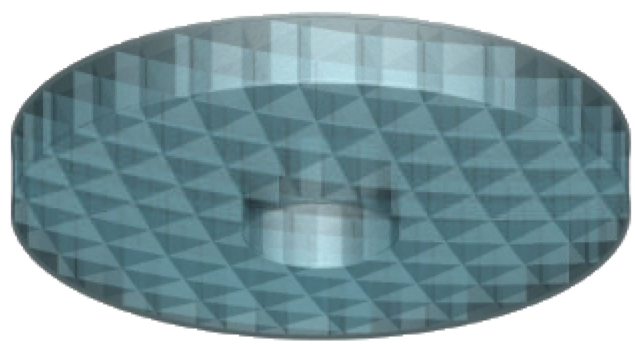
SNAP Sunny-side up



SNAP Primary Mirror Substrate (80% Lightweight / Hytec Study)

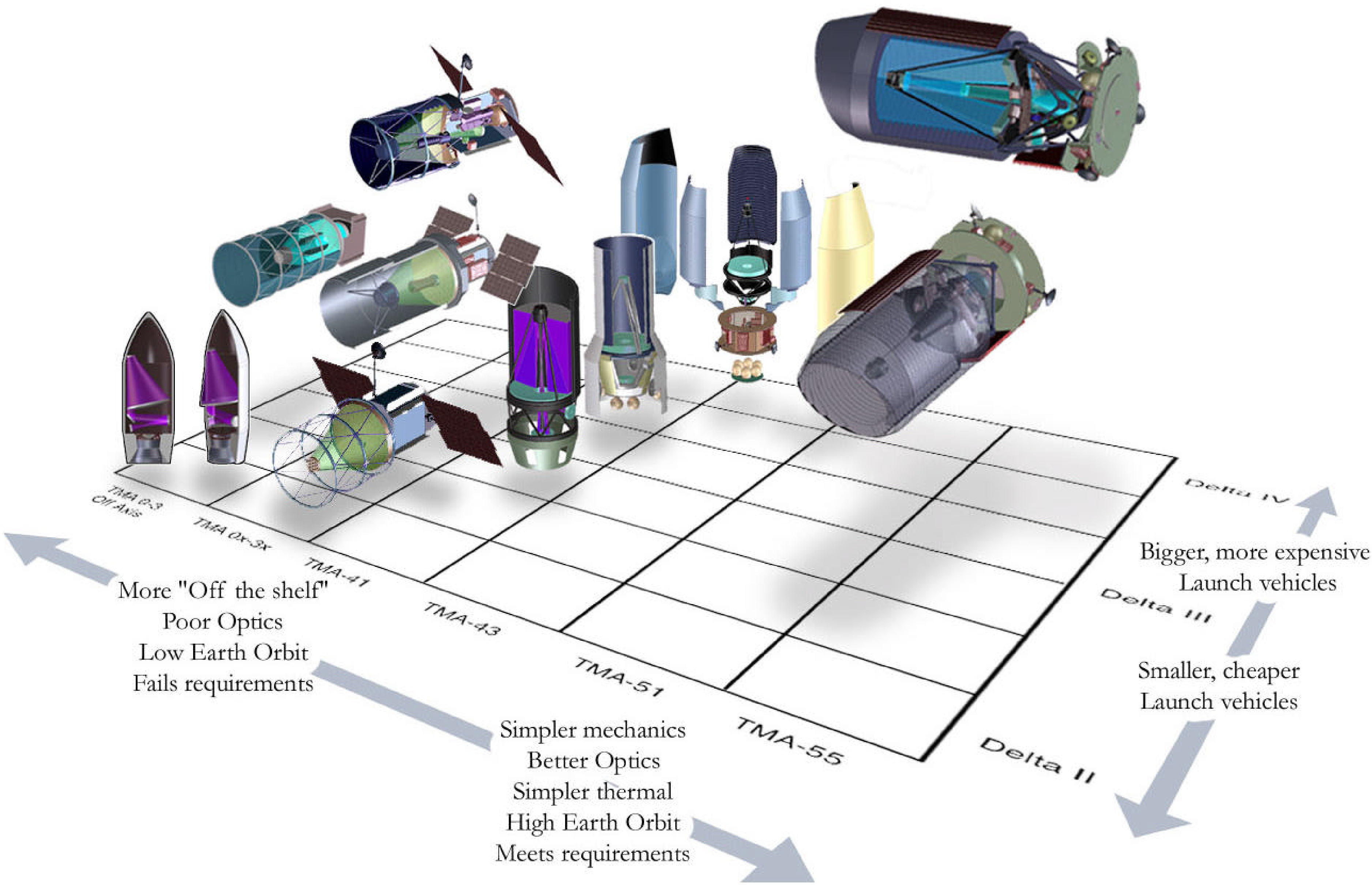
- Key requirements and issues
  - Dimensional stability
  - High specific stiffness (1G sag, acoustic response)
  - Stresses during launch
  - Design of supports
- Baseline technology
  - Multi-piece, fusion bonded, with egg-crate core
  - Meniscus shaped
  - Triangular core cells
- Material
  - Baseline = ULE Glass (Corning)
  - Could be Zerodur (or SiC, S100)
  - Kodak proposed 95% lightweighted ULE for SSO concept study (state-of-art)
  - SNAP can be 80% - like HST
- Can be old technology
  - Simple, simple, simple



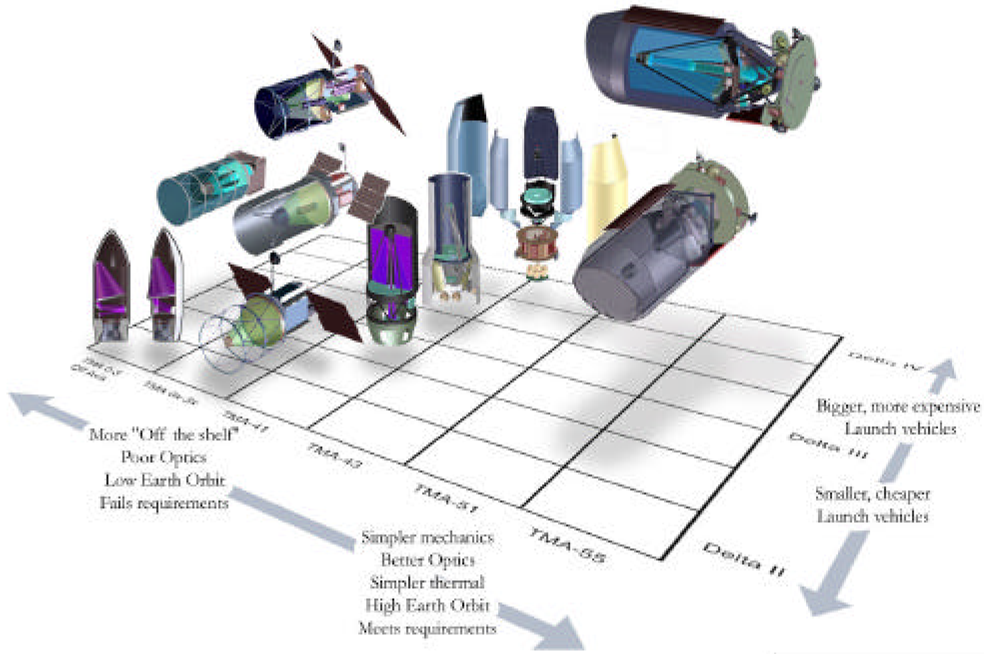


Initial design for primary mirror substrate: 334 kg

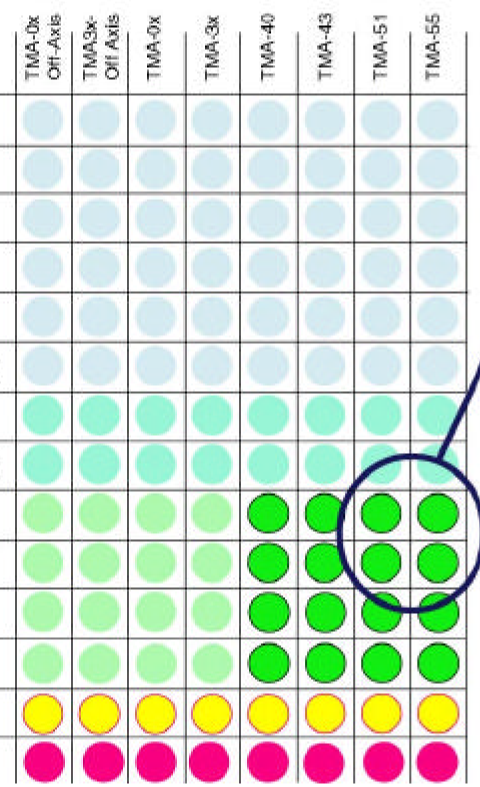
Payload Study



Launch Vehicle Study



Space Transportation System	24,000 Kg	$ 500 M
Titan IVB/Centaur/SRMU	8600 Kg	$ 250 M
Ariane 5	6800 Kg	$ 200 M
EELV-Heavy	6120 Kg	
H2-A	6000 Kg	
Proton	4800 Kg	$ 50-70 M
H2	4000 Kg	$ 150 M
Sea Launch I/Zenit 3	3300 Kg	$ 50-70 M
Atlas II ARS	3100 Kg	
Delta IV	2800 Kg	$ 100 M
Delta III	2700 Kg	$ 80 M
Atlas II AR	2100 Kg	$ 95 M
Delta II 7920 H-10L	900 Kg	$ 80 M
Delta II 7925	1260	$ 70 M



We are HERE

Anything is possible

Will certainly work, and we can expand the mission

Works, and we have data points to show how

Will probably work but we havenít tried it.

Might work but will take a Heroic effort

Won't work

Mass

- **Delta IV-M baseline vehicle**
  - **2800 kg to SNAP orbit**

Component / subsystem	Mass (kg)	
Primary Optics Bench	150	
Primary Baffle	150	
Thermal Shield	150	
Primary Mirror	350	
Secondary Mirror Assembly	32	
Tertiary Mirror Assembly	50	
Central Baffle	5	
Folding Mirror Assembly	5	
Focal Plane Instrument	150	
Filters/Shutter	85	
Ancilliary Instruments	30	
Kinematic Mount	40	
Spacecraft	500	
Instrument Electronics	120	
TOTAL	1817	

SNAP Instrumentation Suite

Key Instruments:

1) GigaCAM

1 sq. deg FOV

142 3kx3k CCD's

2) IR Photometer

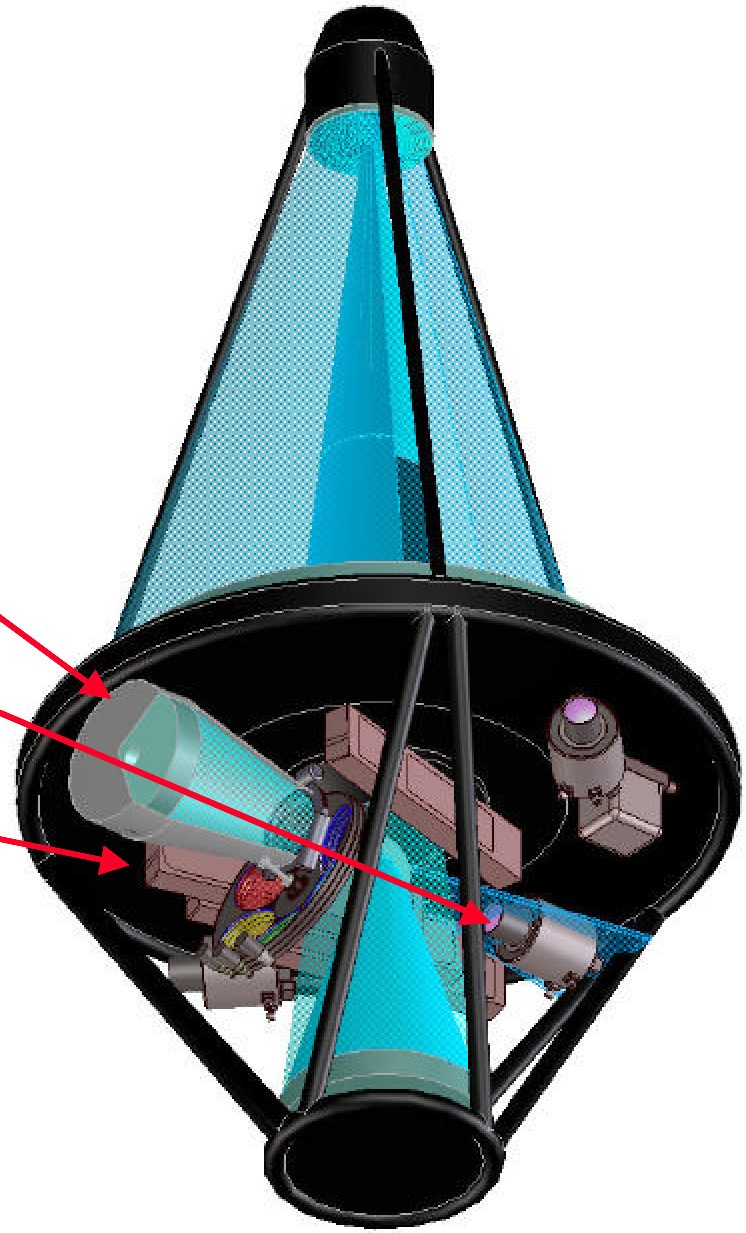
(small field of view)

3) 3-arm spectrograph

350-600 nm,

550-1000 nm,

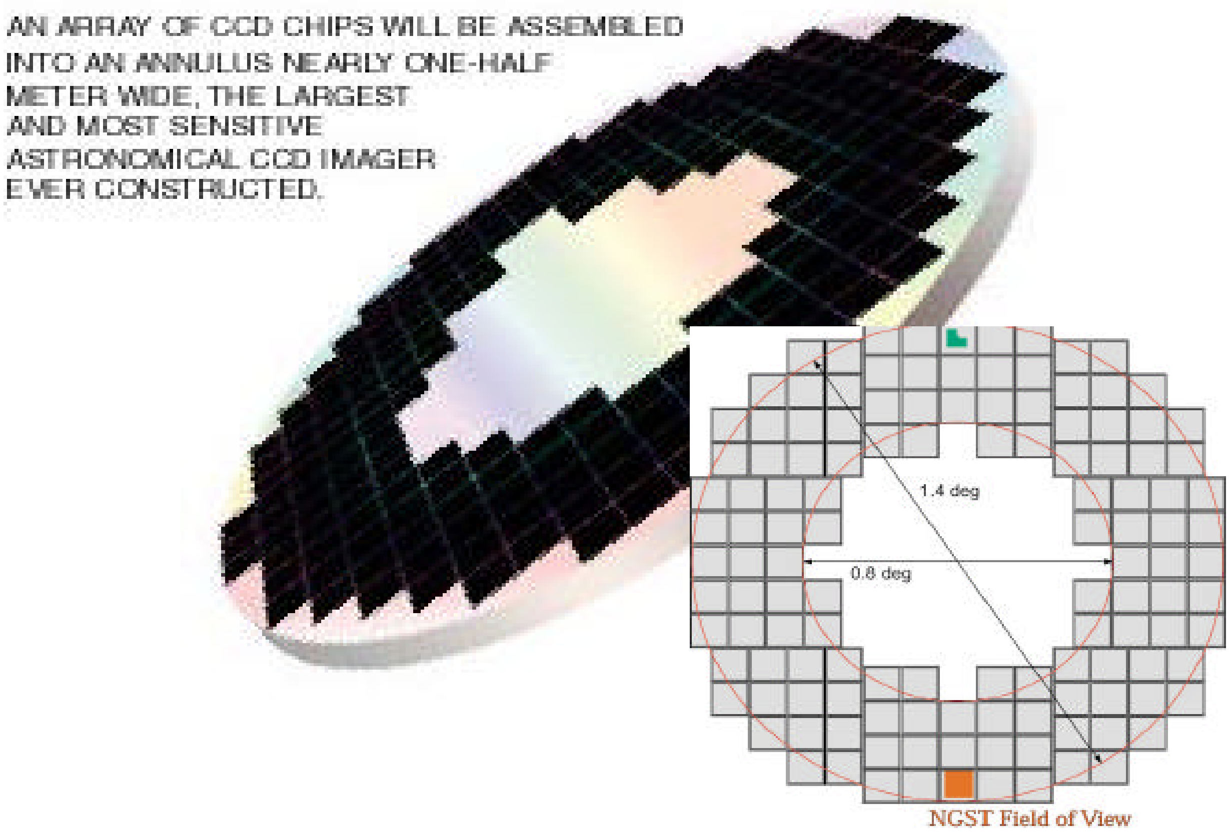
900-1700 nm



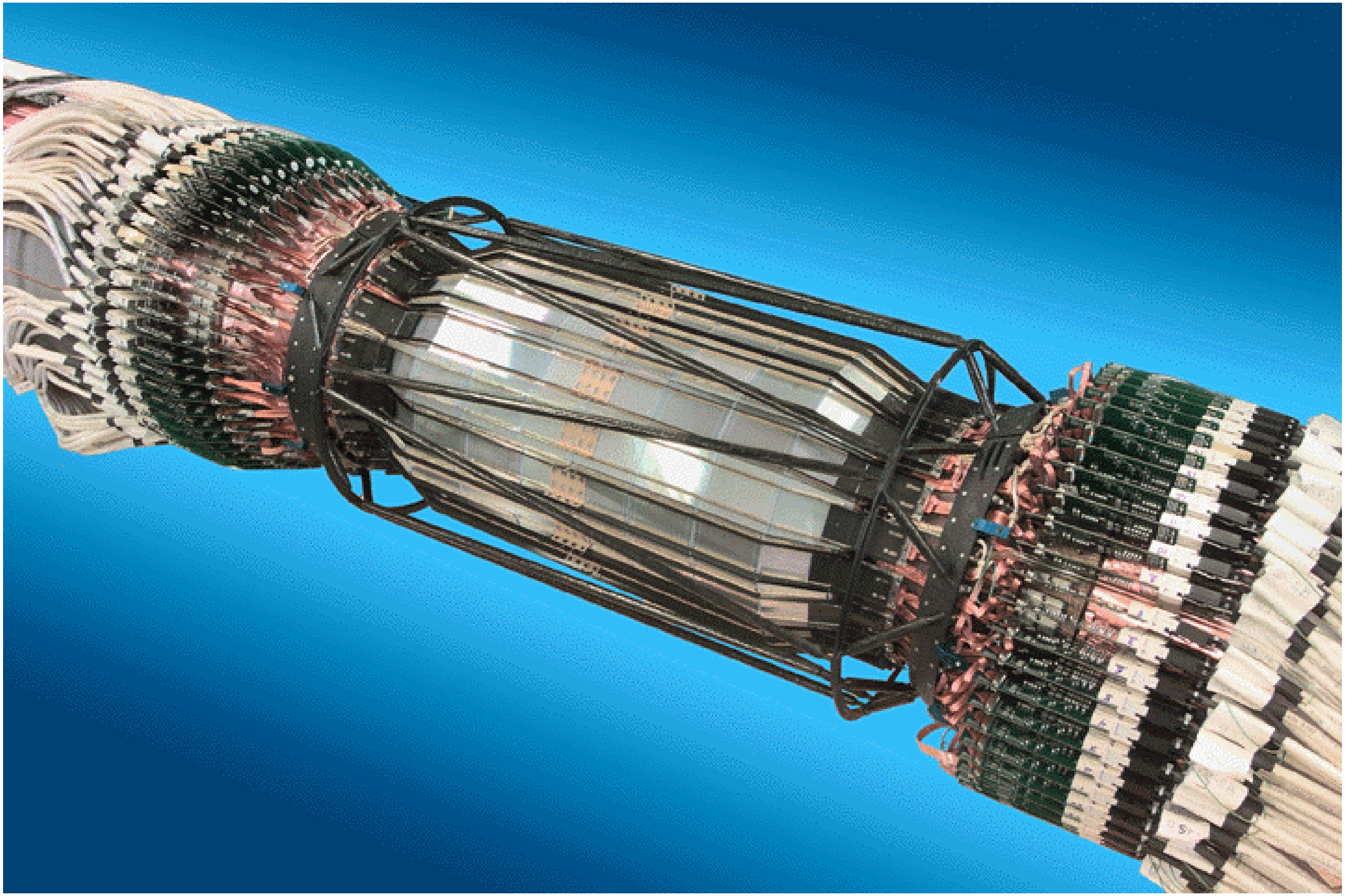
GigaCAM

GigaCAM, a one billion pixel array

- Depending on pixel scale approximately 1 billion pixels
- ~140 Large format CCD detectors required
- Looks like the SLD vertex detector in Si area (0.1 - 0.2 m^2)
- Larger than SDSS camera, smaller than BaBar Vertex Detector (1 m^2)



BaBAR Silicon Vertex Detector (~1m^2 Si)

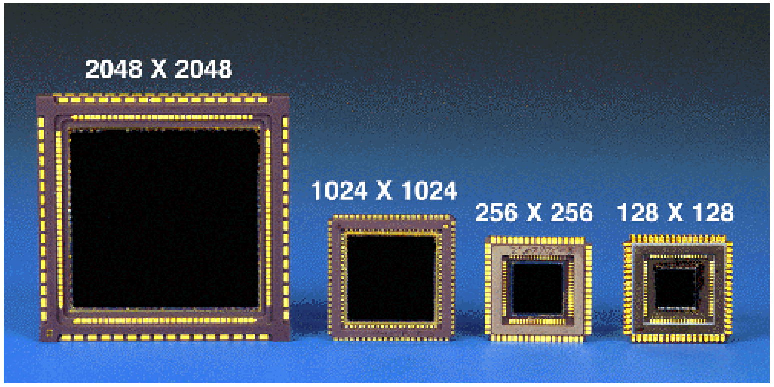


Optical Photometry Parameters

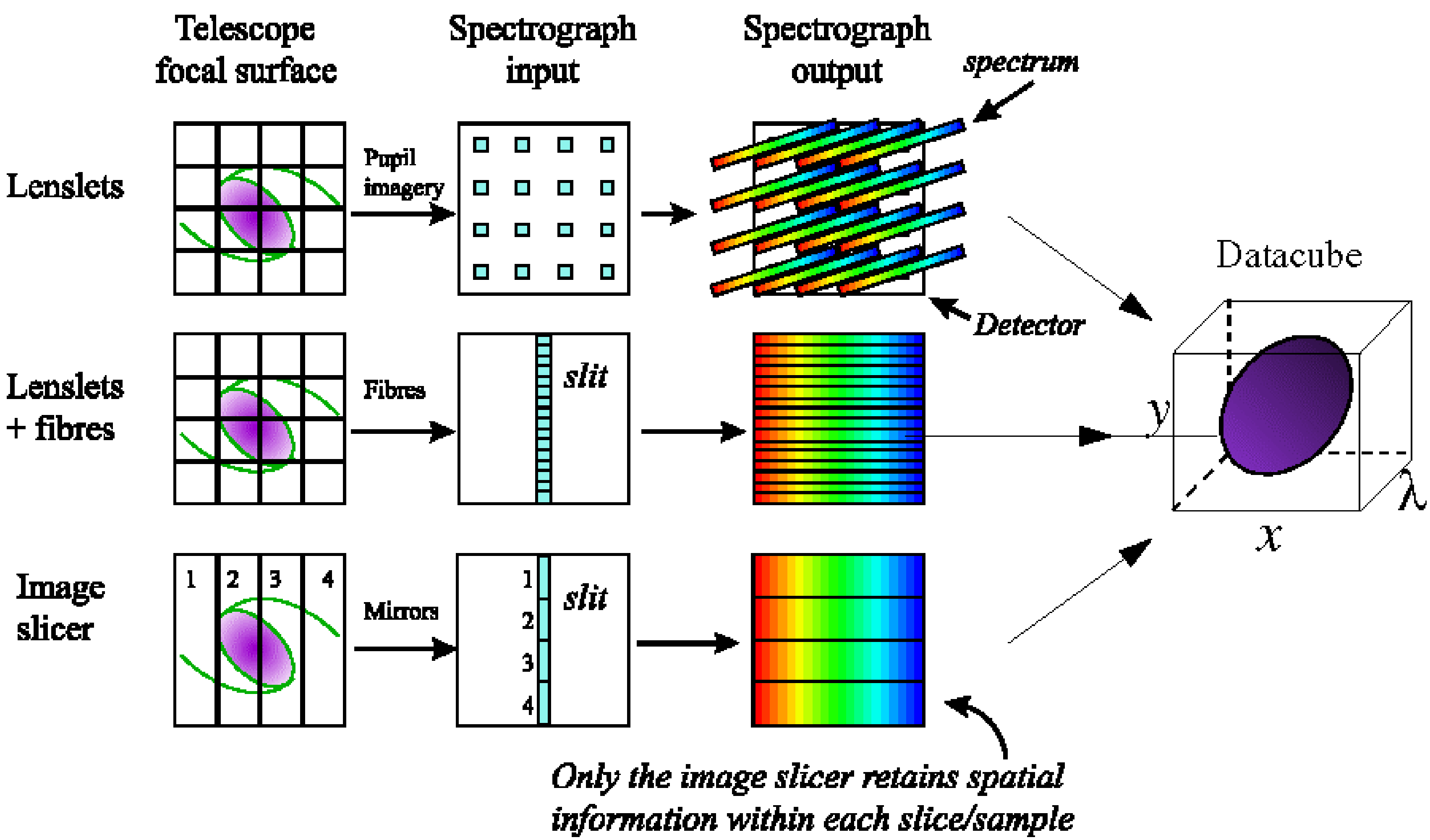
Field-of-view	1° x 1°
Plate Scale	0.07 to 0.10 arcsec/pixel
Wavelength coverage	350nm - 1000nm
Detector Type	High-Resistivity P-channel CCD’s
Detector Architecture	3k x 3k
Detector Temperature	135 - 150 K
Quantum Efficiency	65% 1000nm, 92% 900nm, >85% 400-800nm
Read Noise	4 e-
Exposure Time	up to 1000 sec (single exposures)
Photometric Accuracy	1% (relative)
Dark Current	0.04 e-/sec/pixel

IR Photometry Parameters

Field-of-view	1’ x 1’ up to 10’ x 10’
Plate Scale	1 pixel ~ 0.1 arcsec
Wavelength coverage	1000nm - 1700nm
Detector Type	HgCdTe (1.7 μm cut-off)
Detector Temperature	130 – 140 K (to achieve dark current)
Read Noise	5 e- (multiple samples)
Dark Current	0.05 e/sec/pixel



Spectroscopic Integral Field Unit Techniques



Spectrograph Parameters

Optical Arm:

Spectrograph architecture	Integral field spectrograph, two arms
Wavelength coverage	350-600 nm, 550-1000nm
Spatial resolution of slicer	0.07 – 0.15 arcsec
Field-of-View	2” x 2”
Detector Architecture	1k x 1k, CCD
Detector Array Temperature	135 - 150 K
Throughput	45%
Read Noise	2 e-
Dark Current	0.08 e-/min/pixel

IR Arm:

Spectrograph architecture	Integral field spectrograph (one - two arms)
Wavelength coverage	1000 to 1700 nm
Spatial resolution of slicer	0.12 – 0.15 arcsec
Field-of-View	2” x 2”
Detector Architecture	1k x 1k, HgCdTe
Detector Array Temperature	120 - 140 K (to achieve dark current)
Throughput	35%
Read Noise	4 e- (multiple samples)
Dark Current	1 e-/min/pixel

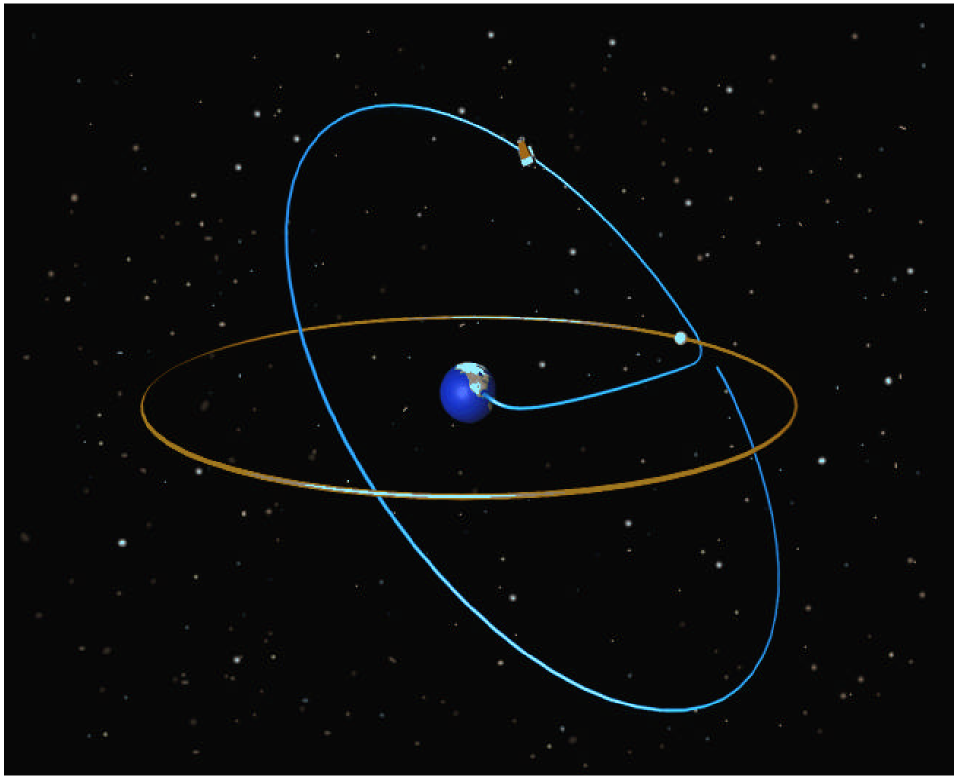
Implemented as either a single triple-arm instrument or two dual-arm instruments

Example SNAP Observing Plan

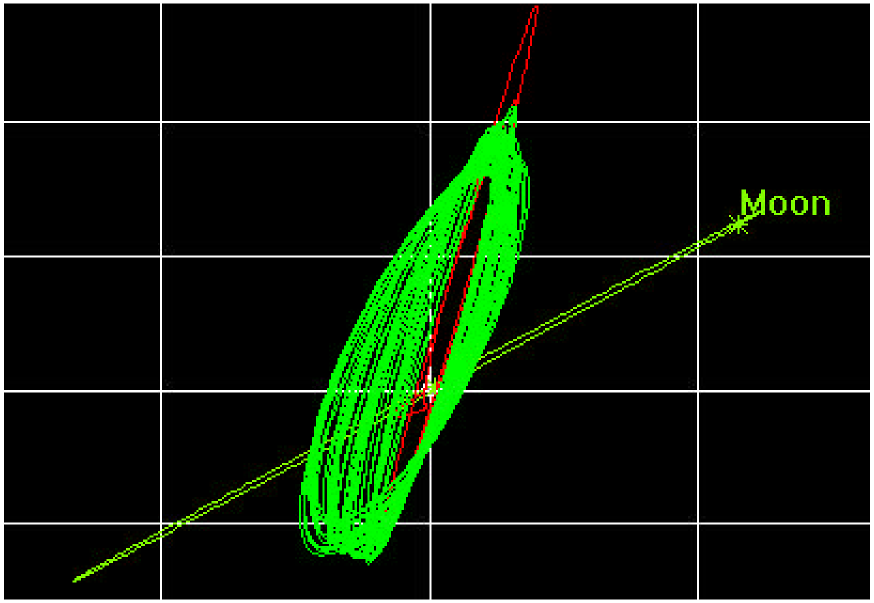
Redshift	# Sne follow	Fields	Detection [days]	Photometry [days]	Spectroscopy [days]	Color[days]
0.1	14	20		8.4	0.1	
0.2	44	20		8.4	0.2	
0.3	82	20		8.4	0.4	
0.4	124	20		5.6	0.7	
0.5	162	20		5.6	1.6	
0.6	196	20		11	2.8	
0.7	226	20		11	5.6	
0.8	250	20		11	8.7	
0.9	270	20		14	12	3.7
1.0	286	20		22	15	5.4
1.1	298	20		34	21	7.4
1.2	304	20		51	29	10
1.3	30	2		12	10	1.4
1.4	30	2		17	14	1.7
1.5	22	2		16	15	1.6
1.6	16	2		16	15	1.5
1.7	12	2	48	15	15	1.4
total	2366		48	268	167	34

Orbit Optimization

- "Prometheus" Orbit Baselined Following Preliminary Trade Study
- Uses Lunar Assist to Achieve a 14 day (19 X 57 Re) Orbit, or 7 day (8 X 40 Re) Orbit with a Delta III 8930 or Delta IV-M Launch Vehicle
- Good Overall Optimization of Mission Trade-offs
- Low Earth Albedo Provides Multiple Advantages:
  - —Minimum Thermal Change on Structure Reduces Demand on Attitude Control
  - —Excellent Coverage from Berkeley Groundstation
  - —Outside Radiation Belts
  - —Passive Cooling of Detectors
  - —Minimizes Stray Light

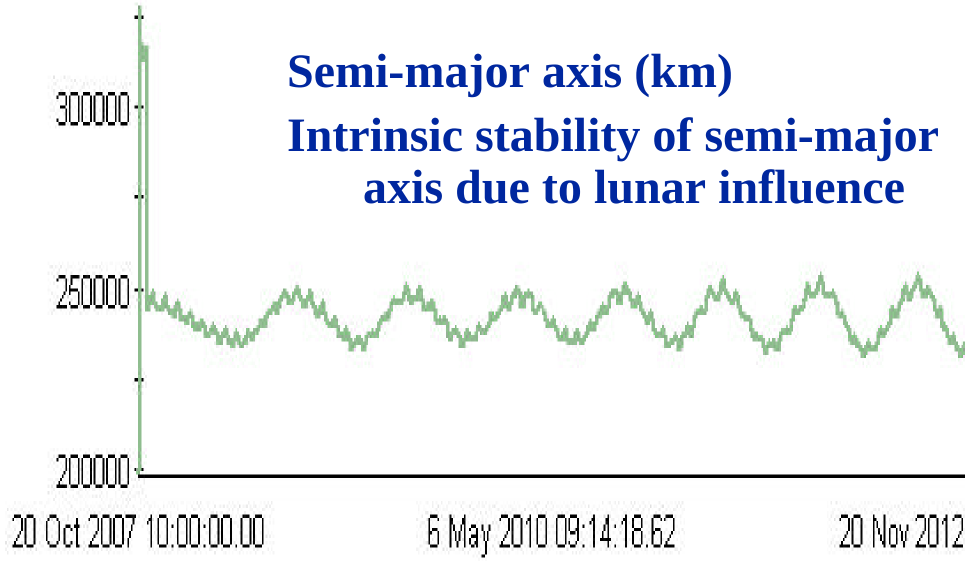


Orbital Stability



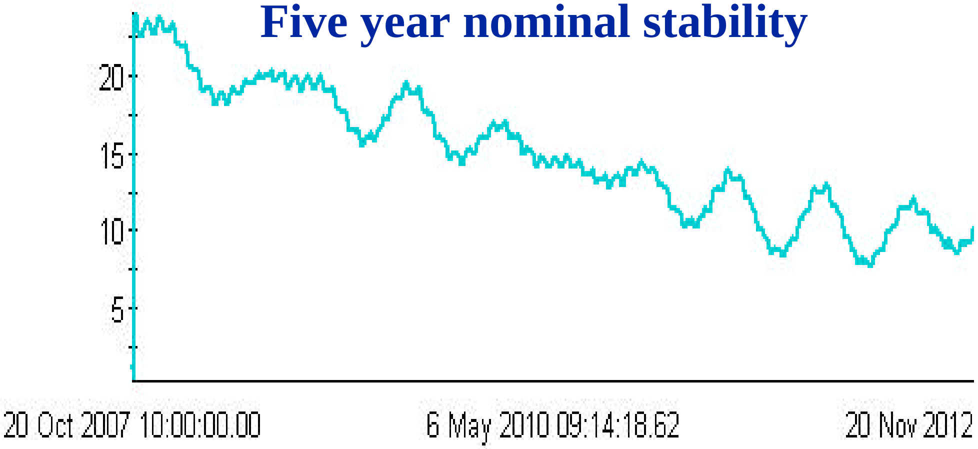
Semi-major axis (km)

Intrinsic stability of semi-major axis due to lunar influence



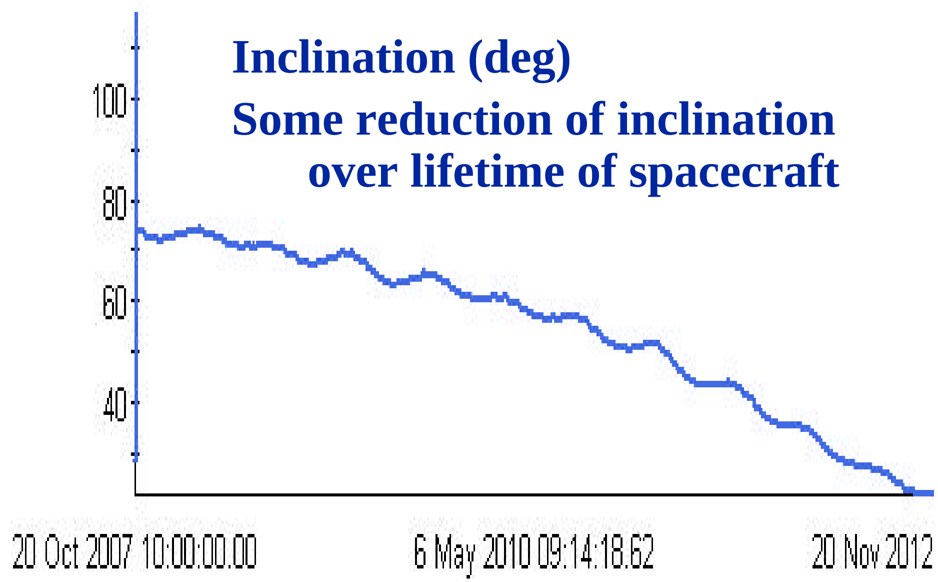
Perigee radius (Re)

Five year nominal stability



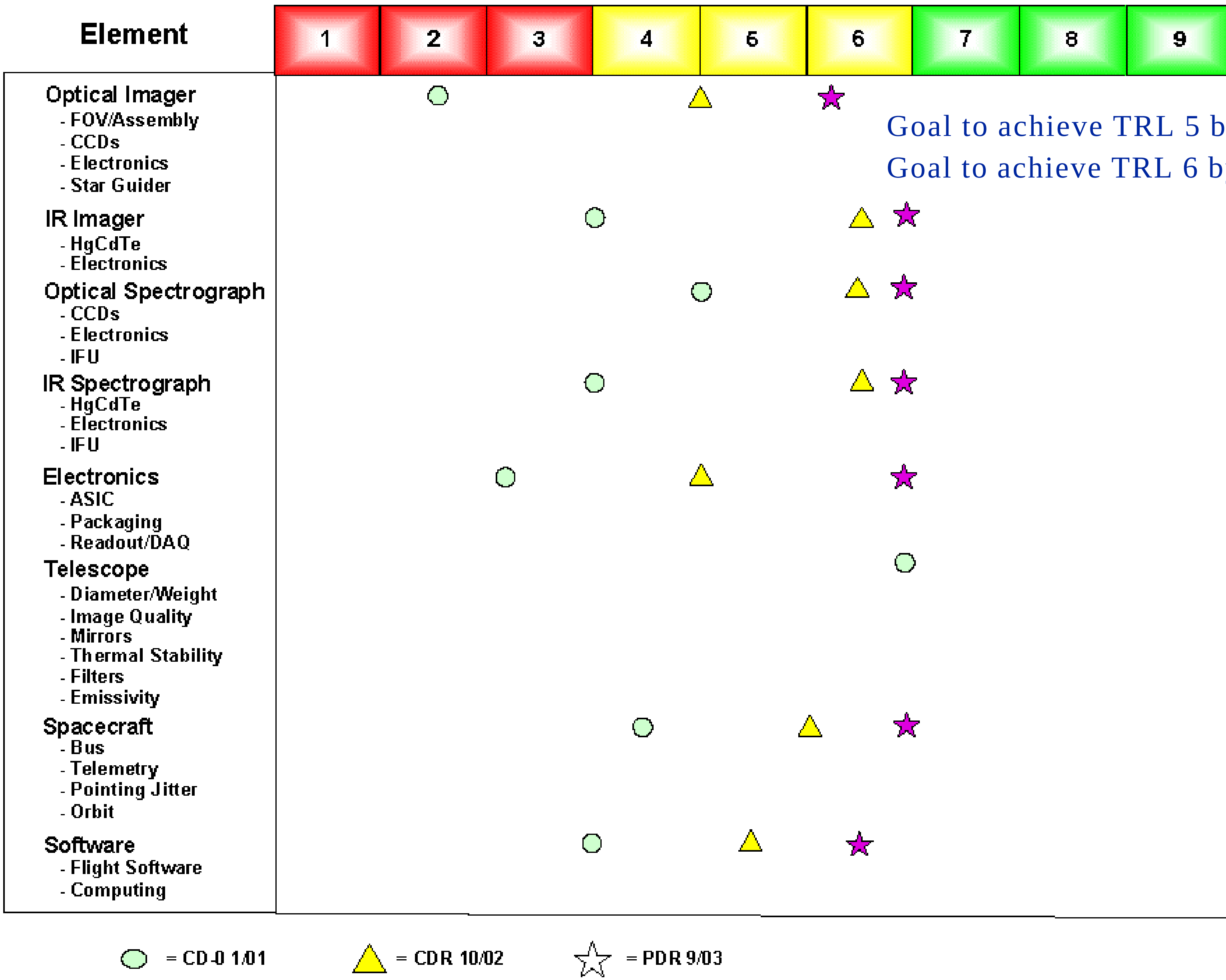
Inclination (deg)

Some reduction of inclination over lifetime of spacecraft



Technical Challenges

Technology Readiness Level / Risk Probability



Goal to achieve TRL 5 by the CDR

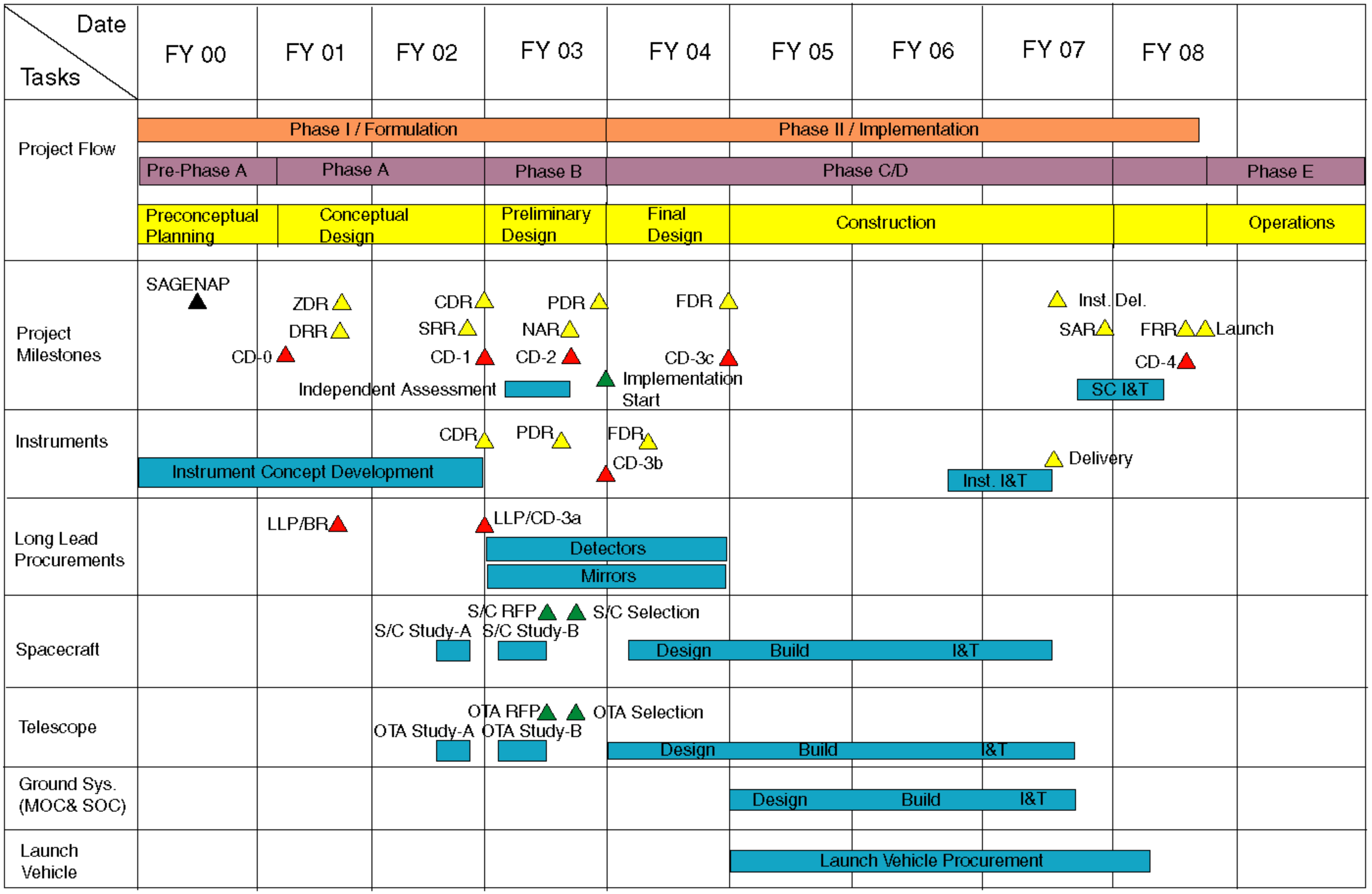
Goal to achieve TRL 6 by the PDR

What is CD-0 ?

PROJECT ACQUISITION PROCESS AND CRITICAL DECISIONS					
Project Planning Phase		Project Execution Phase			Mission
Preconceptual Planning	Conceptual Design	Preliminary Design	Final Design	Construction	Operations

CD-0	CD-1	CD-2	CD-3	CD-4
Approve Mission Need	Approve Preliminary Baseline Range	Approve Performance Baseline	Approve Start of Construction	Approve Start of Operations or Project Closeout

Preliminary Schedule



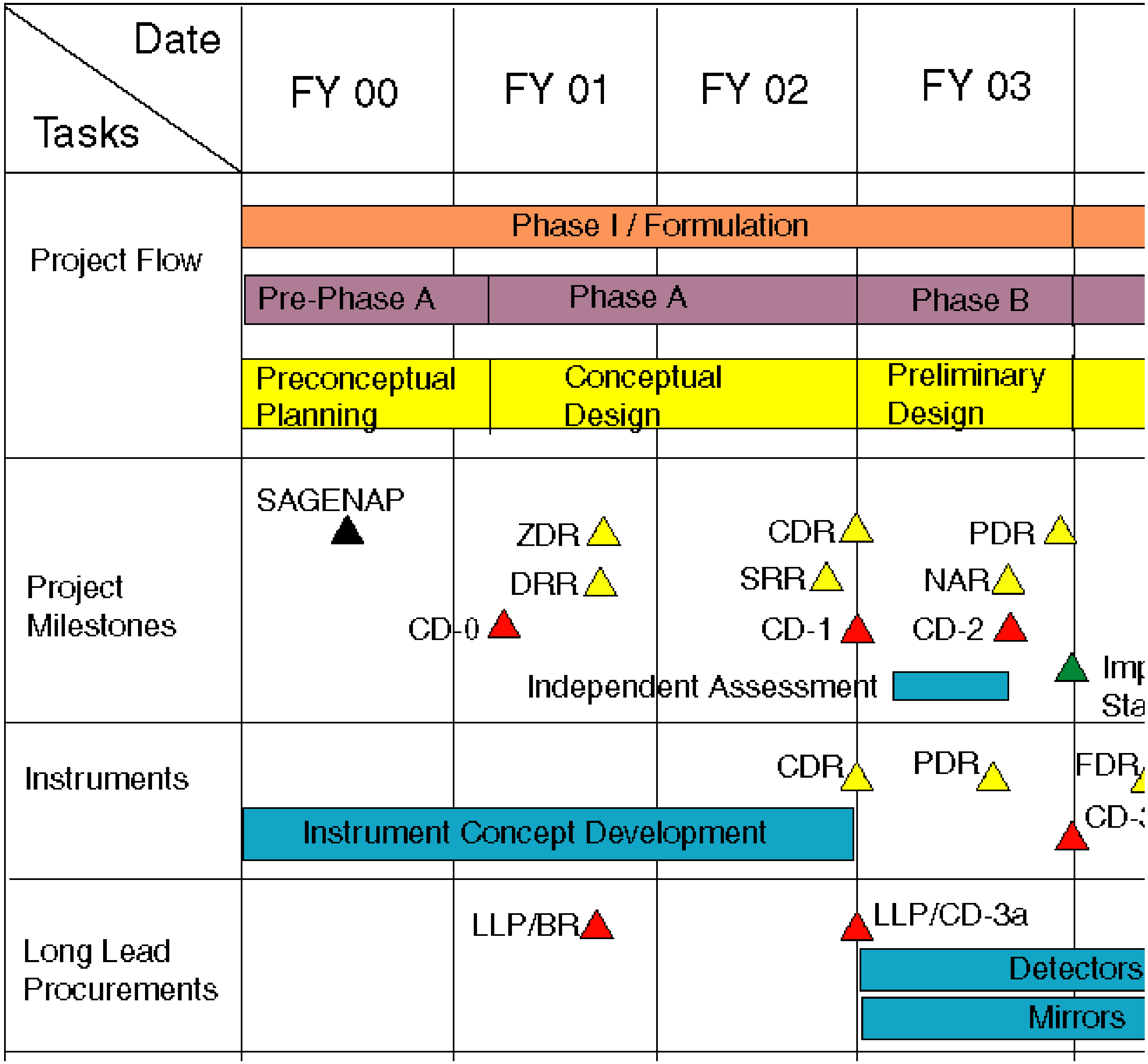
CDR - Conceptual Design Report
FDR - Final/Critical Design Review
FRR - Flight Readiness Review

DRR - Draft Requirements Review
NAR - Non-Advocate Review
PDR - Preliminary Design Review

SAR - System Acceptance Review
SRR - Systems Requirement Review
ZDR - Zeroth Order Design Report

LLP/BR - Long Lead Procurement Budget Req.

Preliminary Schedule



R&D Activities in 2001

- **Demonstration and Validation**
  - — prototyping of CCD's, and imager
  - — radiation testing of CCD's
  - — industrialization of CCDs for GigaCAM
  - — 1.7 micron cut-off HgCdTe validation studies
  - — testbedding facilities
- **Mission Requirements and Design Optimization**
  - — refine reference mission and revise mission requirements
  - — conduct and document trade studies
  - — develop integration and test plans
  - — risk analysis and mitigation
  - — produce Telescope Assembly draft requirements/specifications
- **Project Management**
  - — develop cost models and cost estimating relationships
  - — define acquisition strategy
  - — further develop collaboration
  - — further develop management & collaboration structures

Summary

- Pre-conceptual Phase at end
  - Technology and risk areas issues are known
  - Clear mission feasibility
  - Instrumentation concepts / telescope ready for optimization

- Documentation in hand:
  - Science proposal, mission definition and requirements document, optical telescope assembly requirements, draft risk assessment, R &D plan, management plan

- Requirements driven
  - Draft requirements mid-summer to drive an efficient conceptual design

- Engineering work on SNAP is ramping up to establish costs and trade-offs

- Core science & engineering team in place

- On track for a successful conceptual design phase

- Incredible progress in key technology areas to report in talks following ...